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Original Article

DEVELOPING A HYBRID TRANSMISSION SYSTEM FOR TWO WHEELER AUTOMOBILES

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ABSTRACT

This paper mainly focuses on developing new transmission drives for Hybrid drive systems. In the current world, we can observe different Hybrid drive systems in which Toyota Prius is one of the well-known hybrid drive system, but the problem with these systems are that they are large in size and the initial investment for manufacture is quite high which makes them confine to four wheeler drives. By a survey, most of the countries of Asia continent use motorcycles as their primary mode of transportation. So, hybrid motorcycle is one of the ways to reduce these pollutants from motorcycles so the need of less spaced and low cost hybrid system is needed, so in this paper we are mainly focusing on less spaced cost convenient hybrid transmission drives. This transmission need not be altered manually, for different rids which makes the ride easy and convenient.

KEYWORDS: Hybrid Drive System, Continuous Variable Transmission, Centrifugal Clutch & Transmission System

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ACRONYMS AND NOMENCLATURE

a	length and diameter (mm)
μ	Coefficient of friction
Θ	angle of contact of belt

1. INTRODUCTION

In the present world oil, which is lifeblood for industrialized nations like Venezuela, Saudi Arabia, Iran, Iraq is playing a very dominant role. Governance cannot control the fluctuation in prices of oil. The transportation of fuels has been always a firm way to distribute all over the world. So, everyone is in search of alternative fuels. When these alternative fuels occupy the industrial market, we can depend on hybrid technology that compensates the transportation.

Most people in India use two wheeler bikes for daily transportation and it is around 37 million motor cycles. So our idea revolves around it, to make a hybrid motor bike for a longer range with the low cost. It is a dual fuel system, where gasoline supports the engine and another one is a motor that is supported by electricity.

Here, we use BLDC motor for transmission because it is compact and can easily mount, less amount of heat dissipation when compared to brushed motor, simple mechanism and power control of BLDC motor is easy to implement. This BLDC has 85-90% efficiency runs at high operating speeds and quick in response. Now a days,

most HEV's are using BLDC motor, because the peak point efficiency is high and rotor cooling is simpler. Battery supports the motor to run at required intervals. A down sized engine is also used having a capacity of 125cc.

2. LITERATURE SURVEY

[10]The world has 53.3 years of oil left at the current rate of production, according to BP's annual statistical review of world energy. With an increase in the population, this situation may become worse, because of that world have to depend on alternative fuels, for that the first step can be Hybrid technology. The biggest advantage of hybrid car over gasoline powered car is that it runs cleaner and has better gas mileage which makes it environmentally friendly. A hybrid vehicle runs on twin powered engine (gasoline engine and electric motor) that cuts fuel consumption and conserves energy. Typical HEVs consist of an internal combustion engine, electric motor, single or multiple energy storage systems, power electronic converters, and controllers.

Firstly, there are two types, connections to drive train one is series connected where the engine is connected to the motor and the motor connected to the drive system and another one are the engine and motor are separately connected and manually altered when they required. Most simple way to achieve our aim is by parallel hybrid topology which both individually drive the car or both coupled up jointly giving drive.

2.1 Necessity for Choosing Hybrid Bike

As mentioned above, 36 million motor bikes are in India. If we want to switch it to other alternative resources like electricity, solar, etc. So all motor bikes can't be switched at one stroke into electrical because of their financial and some automobile manufacturers may get into losses. So, Hybrid technology will be a better solution for phase change from gasoline to electric. Hybrid bikes can be used for certain period of time and can hold the market for automobile manufactures. Another advantage of this hybrid technology is, a gasoline bike doesn't need to be scraped. We can make minimal changes to the gasoline vehicle and can be used as a hybrid bike.

Another major problem in the present world is Pollution.

There is one article which states "Motorbikes '16 times worse than cars for pollution". Tests on a selection of modern motorbikes and private cars revealed that rather than being more environmentally-friendly, motorbikes emit 16 times the amount of hydrocarbons, including greenhouse gases, three times the carbon monoxide and a "disproportionately high" amount of other pollutants, compared to cars.

Table 1: Emission from Vehicles at varied Speeds (gm/km)

Speed (kmph)	Motorbike		Truck	
	Carbon Monoxide	Hydro carbons	Cardbon monoxide	Hydro carbon
10	33.02	4.47	22.6	5.7
25	21.20	2.60	14.6	2.3
50	9.80	1.30	8.2	0.0

2.2 Tractive Force Calculations for a Motorcycle

To design a transmission system, the primary factor is to look for the amount of torque required for the motorcycle to outcome static friction.

Most of the motorcycles weighs 150 Kg.

Wheel base (L) = 1320mm

Front wheel weight (Wa) = 90 Kg

Rear wheel weight (Wb) = 60 Kg

General equation to find height of

[7]C.G = (0.277*L)+(0.045*L) = 425 mm

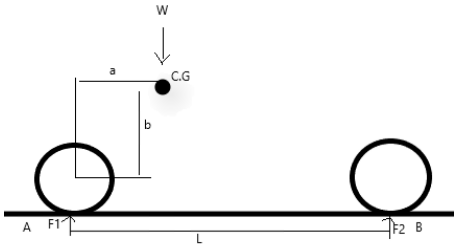

Figure 1: FBD of Motorcycle

Here,

F1= Weight on front tire

F2= Weight on rear tire

W= Total weight of motorcycle

A= Front tire contact point

B= Rear tire contact point

C.G= Centre of gravity of motorcycle

a= Horizontal distance from front wheel to C.G

b= Height from front wheel center to C.G

f = Rolling friction of motorcycle (0.02)

μ= Static friction between tire and asphalt

[4]Sum of moments at C.G will be zero

So,

F1*a = F2*(L-a)

90*a = 60*(1320-a)

Finally, a = 258 mm Or a= (f2*L)/W

And C.G height (b) = 425mm

Tractive force on rear wheel can be given as

[5]Fmax= (μW/L(a-fh))/(1-μb/L)

Using the above formula, we can obtain the tractive force which can help in obtaining drive ratios in transmission system.

So in this condition, maximum tractive force on rear wheel is obtained as Fmax = 522.84 N

And, generally, motorcycle tyres are at radius of 17 inch;

So torque output needed for the motorcycle is

[12]Torque output = Fmax * Radius of tire= 225.34 N-m

To attain this torque output, the vehicle should have different gear ratios. But hybrid system requires automated drive. So, transmission system for I.C engine is occupied with Continuously Variable Transmission (CVT) system which can obtain different drive ratios automatically and with less space and cost.

2.3 Design of Continuous Variable Transmission (CVT)

CVT is a unconventional step-less transmission system connected to IC engine, where continuous and infinite gear ratios in a designed limit between maximum to minimum. In most drive systems equipped on motor bikes have only 4-6 particular gear ratios which are selected to convert the engine speeds. This infinite variability of gear ratio, CVT allows the engine to maintain a constant speed while the vehicle increases in velocity. This can result in better vehicle performance.

In drive system of hybrid bike CVT type transmission system plays a crucial role because of various factors, they are efficient at low speeds, Less weight and the simplest transmission system, Less pollutants, Supplies more faster acceleration when compared to semi/automatic transmission type, Complex design and smooth transmission, Step-less transmission type, Cost effective, No bulky gear sets, Less maintenance.

2.4 Designing of Continuously Variable Transmission

Among all these types of pulley CVT system, Pulley-type CVT is more efficient, cost effective and easy to manufacture.

Continuously Variable Transmission (CVT) design is divided into Engine selection and its performance, Pulley design, Belt design[13].

2.5 Engine Parameters

To design a CVT transmission, we selected 150cc commercial engine.

Maximum power =7.5kw

Maximum torque =18.6 Nm

Initial rpm N1 =3600

2.6 Speed Ratios for CVT

Firstly, the maximum and the minimum speed reduction required to have the desired performance of motorbike is calculated below.

For a vehicle to have maximum speed of 80 kmph, the required rpm of the wheel having 22(558.8m) tyre

diameter can be calculated as[1],

Maximum speed of car (v) = 80 kmph = 22.22 m/s

Tire rim diameter (d) = 22 inches = 558.8mm

Tire rpm (N2) for max speed (N)

[1]N= (V*60)/(π*D) = (22.22*60) / (3.14*0.558)

= 761.82 rpm

Where, V = Speed of the Vehicle, D = Diameter of the wheel driven

[1]From PSG design data book, we considered the cross-section symbol as "B" for certain load (2-15 KW) and diameter is considered as D1=150mm.

Relation speed and gear ratio:

N1 × D1 = N2 × D2

D2=44mm.

2.6 Design of Pulleys

[2]Disks are made up of mild steel.

Disks have tapered surface of 13 degree on each side of the disc to work as a pulley when comes in contact.

Density of mild steel = 7860kg/m3

Diameter of the disc = 150mm

Thickness of the disc = 8mm

2.7 Tapered Pulley

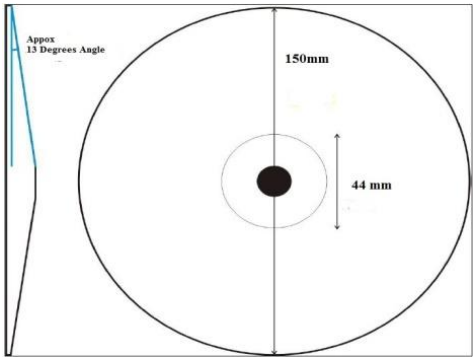

Figure 2: Tapered Pulley

2.8 Belt Design

The v-belt is used to connect the driver pulley and driven pulley. V-belt is used for short centre distance V-belts having friction multiplying effect because of wedging action on the pulley.

By the older drive systems, assumed center distance x=250mm.

lb = (dm π / 2) + (df π / 2) + (2 lfm) + ((df - dm)2 / (4 lfm))[1]

Where, lb = length of belt (mm,)

df = pulley diameter of 1st pulley=150 (mm)

dm = pulleydiameter of 2nd pulley=44 (mm)

π = 3.14

x = centre to centre distance of driver and driven pulleys=250 (mm)

By substituting the values into the equation, we got nominal length as L=823.6mm

From design data book L=923mm is selected according to the availability standards from section B belts

Now, substituting nominal length into the equation we found the exact centre distance which is x=145.85mm

2.9 Arc of Contact

[1]Arc of contact = $180 + 2\sin^{-1}$

Where, df = pulleydiameter of 1st pulley=150 (mm)

dm = pulley diameter of 2nd pulley=44 (mm)

By substituting, we get arc of contact=159 degrees.

[1]Velocity of belt v=(3.14*D*N)/60

V=9.92 m/s

Tensions in Belt

T1/T2 = $e^{(\mu*\alpha*\cos\beta)}$

Where, T1/T2=Tension Ratio

μ=Coefficient of Friction=0.25

α=Angle of Wrap=2.75 radians

β=Groove Angle of V-Belt=26 degrees

we got a relation T1=4.75 T2

we have

P = (T1-T2) * V

By substituting, power=7.75kw and

Velocity, v=9.92m/s.

we solved T1=806.45 N, T2=201.6 N.

Belt Specification

- Belt Grove Angle: 26°
- Mass of Belt: 0.5 kg/m
- Belt Length: 923 mm
- Main Cross Section: 17 mm x 11 mm
- Centre distance between pulleys (C) = 145mm
- Driven pulley diameter (D) = 150mm
- Driving pulley diameter (d)= 44mm.

CAD Model

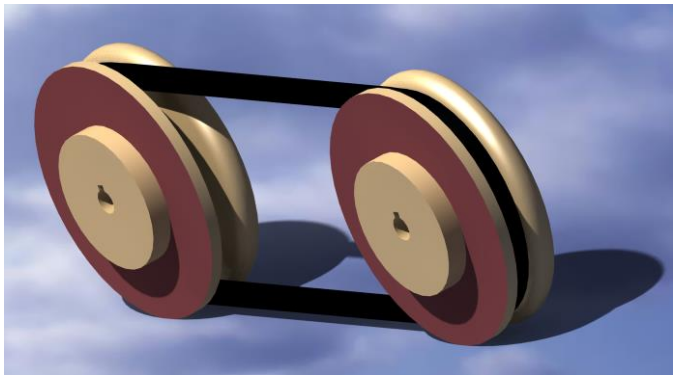

Figure 3: Model of CVT Pulleys.

Design of Compliant Centrifugal Clutch

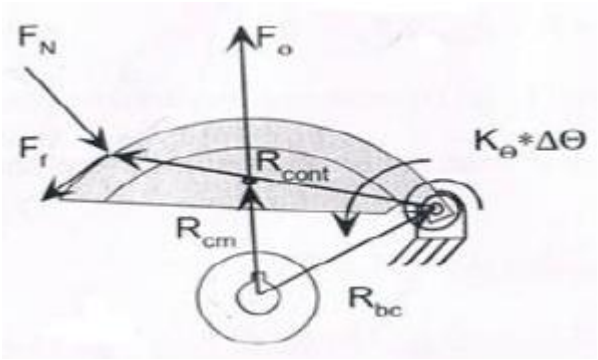

Figure 4: Compliant Centrifugal Clutch Nomenclature

D_{clutch} = 11.91x Dhole

Dd_{rum}=12.80 x Dhole

D_{hole} =d, mm

n=3

Θ=Angle between hole and center of shaft

Width of slot in clutch

W =0.675d

Centrifugal force on clutch:

Fo = M×Rcm×ω²

M = mass of arm, Kg.

ω = Speed of clutch, rad/sec

Normal Force on Clutch

[8]F $= K\Delta\theta k + (Rcm - Rbc) \times Fo - Rcont \times \mu - Rcont$

F= Normal force on arm, N

K=Torsional spring constant

θ=Deflection of arm

μ=co-efficent of friction

Torque Transmitted by a Clutch

T=F×μ×Rdrum×n

Where, T= torque, N.mm

[9]Based upon these formulas, the centrifugal clutch and drum can be designed for centrifugal transmission.

Combined Braking System

It is a framework utilized for connecting front and back brakes on Motorcycle. In this combined braking system, if the rider depresses the left or right brake, this system automatically depresses both the brake so that the vehicle can stop quickly without any skidding. [11]The measure of each brake connected is dictated by a corresponding proportional control valve.

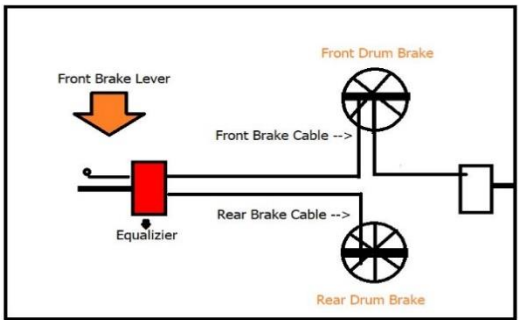

Figure 5: Working of Combi Brake

Working

Now–a–days, all Honda motorcycles scooty types are equipped with Honda's Combi brake technology. The combi brake enables us to use both the brakes with just a brake lever. It decreases the braking separation and improves security while Braking. Here, equalizer ensures distribution of force between front and rear wheel at the same time while giving balance

and comfort for the rider. As we are developing a Hybrid Motorcycle, Regen braking is also important. It is a known fact that a less amount of energy is conserved through Regen Braking. To gain the drive range that amount f conservation of energy through Regen is also important.

3. CENTRIFUGAL TRANSMISSION

Centrifugal Clutches

The centrifugal clutch is a clutch type which uses centrifugal force to connect the drum. The driving shaft is connected to the output pulley of CVT. When driving shaft starts rotating by using centrifugal force, the springs starts expanding and it pushes shoes to the drum. When the friction lining is connected to the drum, then the drum starts rotating.

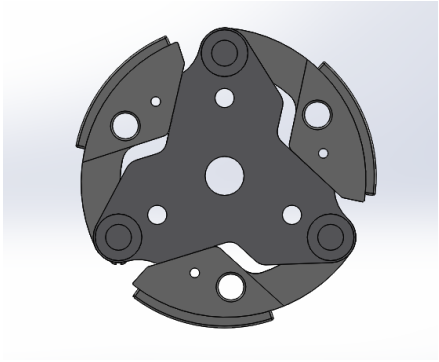

Figure 6: Model of Centrifugal Clutch

Drum

In this Centrifugal transmission system, Drum will act as the input pulley of the mechanism. When centrifugal clutch starts rotating, due to centrifugal force when frictional lining is touches drum, drum starts rotating and drum acts as the input pulley.

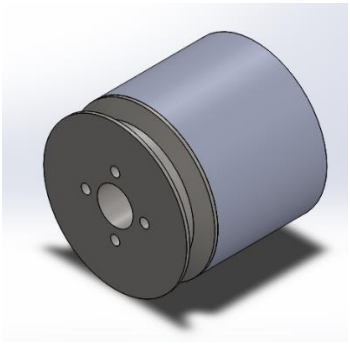

Figure 7: Model of Drum.

Ball Bearing

Ball bearings are used to reduce the rotational friction and support radial and axial loads. In this centrifugal transmission, while CVT shaft or engine shaft is rotating, drum should not rotate. The drum should start rotating due to centrifugal clutch not with shaft. So, ball bearings are used to achieve this kind of motion. There are two ball bearings that are arranged between CVT shaft and drum & Motor shaft and drum.

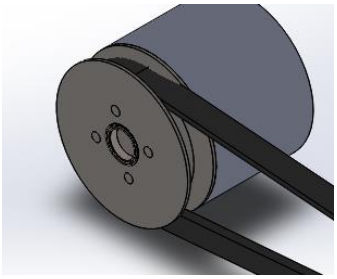

Figure 8: Ball Bearing Arrangement in Drum

Belt Drive

To transmit power to the output pulley which is connected to the rear wheel, Belt drive is used. Due to this arrangement, chain drive may not be more efficient.

Ball Bearing

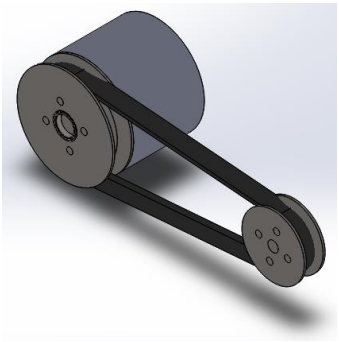

Figure 9: Belt Drive

Working of Centrifugal Transmission

The mechanism is arranged as shown in figure

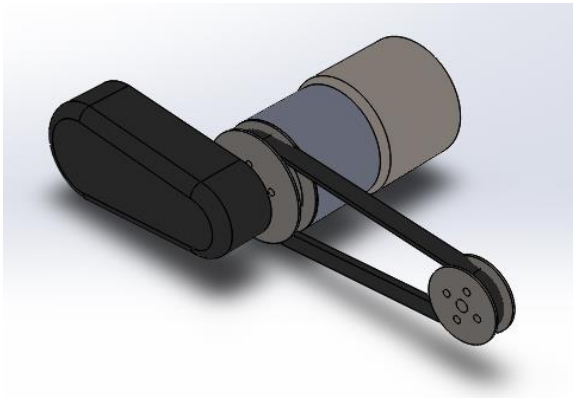

Figure 10: Arrangement of Complete Mechanism

In this, there are two centrifugal clutches are arranged inside the drum.

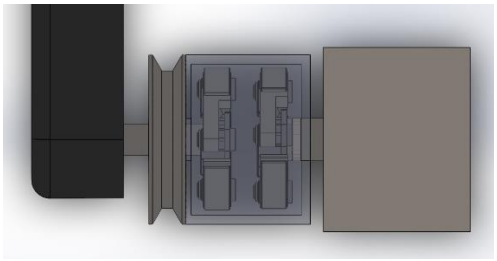

Figure 11: Arrangement of Internal Mechanism

One of the clutches is connected to the output pulley of the CVT and another one is connected to the brushless DC electric motor.

CVT

When rider initiates to drive the motorcycle with engine, where engine is in ON condition, CVT starts rotating because the output shaft of CVT is connected to centrifugal clutch, the clutch starts expanding its friction linings and drum starts rotating.

BLDC Motor

Centrifugal clutches

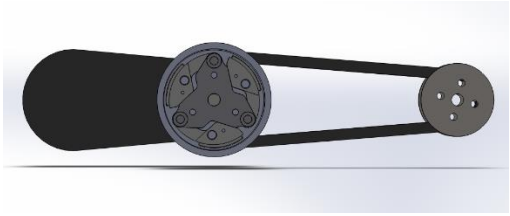

Figure 12: Sectional view of drum

When rider initiates to drive the motorcycle with motor, then the same case will apply.

The advantage of this centrifugal transmission is that motorcycle can use both the engine power and motor power simultaneously without any fluctuations or discomfort to the motorcycle.

Analysis of Centrifugal Transmission Drum

In centrifugal transmission system, the torque should be transmitted from the shoes to the drum with two centrifugal clutches placed in it and hence as per the above calculations, centrifugal clutch needs to transfer 522 n-m. It should also transfer the motion to the wheels through belt drives. By above calculation, the maximum tension in the belt is calculated as 800 n. So, that can be the maximum load on the drum acting as moment and belt tension as a normal force. So, structural analysis is performed to verify safe conditions [3][6].

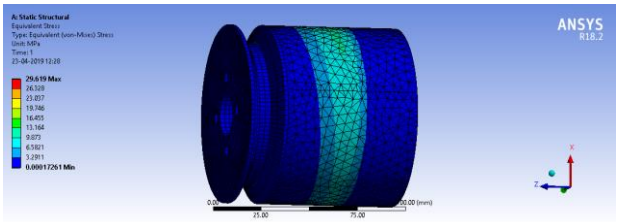

Figure 13: Von-mises stress

Maximum von- mises stress developed at that loading condition is below than yield stress of the structural steel.

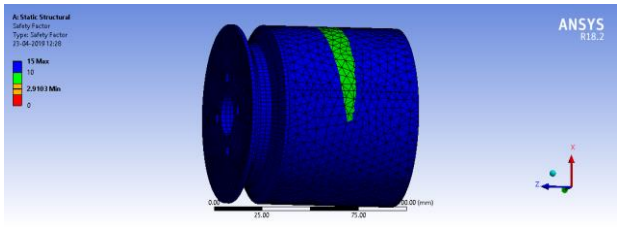

Figure 14: safety factor

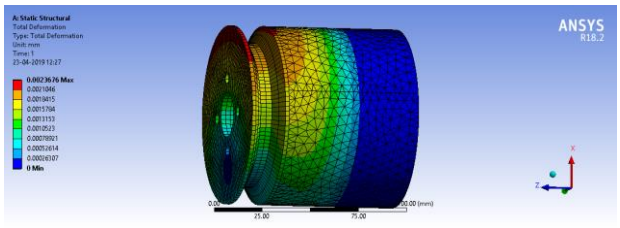

Figure 15: Deformation

CONCLUSIONS

A compact hybrid system for transmitting the power from engine and motor is designed. The design is validated by using catia v5, solid works and ansys 18.2. a reasonable agreement between the theoretical and simulated results is found. Further, it is verified that the design under the maximum loads 300Nm of centrifugal clutch torque and 800N of belt tension with minimum factor of safety 2.91 can withstand the designed criterion. The overall analysis satisfies the constraints of a hybrid motor bike.

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The Design Process is a team effort. All team members worked complementing each other as per the best practice of team play. We would like to show our gratitude towards our Faculty Adviser. We would also like to express our sincere gratitude towards the Mechanical Dept. Faculty and entire management and support staff of the college for extending the support to our team.

FUTURE SCOPE

This paper provides a good idea for transmission system with less space and cost. This paper does not discuss about the thermal reactions and slipping conditions in the system. This heating problem can be achieved by good material analysis and by using sodium friction shoes which has same functioning as sodium valves. In this paper, we have discussed only about the individual powers i.e. if engine runs, motor doesn't work. If we include another electric motor that can be charged while engine is running, then motorcycle can be worked as a PHEVs. There is a scope to develop technology further.

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